Characterizing Mixed-Phase Clouds from the Ground: a Status Report

Contributors
Matthew Shupe, *CIRES/NOAA/ETL*

Research Highlight

The phase composition and microphysical structure of clouds define the manner in which they modulate atmospheric radiation and contribute to the hydrologic cycle. Issues regarding cloud phase partitioning and transformation come to bear directly in mixed-phase clouds, and have been difficult to address within current modeling frameworks. Ground-based, remote-sensing observations of mixed-phase clouds have the potential to contribute a significant body of knowledge with which to better understand, and thereby more accurately model, clouds and their phase-defining processes. Utilizing example observations from the Mixed-Phase Arctic Cloud Experiment (M-PACE), which occurred at the North Slope of Alaska ARM Climate Research Facility (ACRF) during autumn 2004, a group of ARM investigators have reviewed the current status of ground-based observation and retrieval methods used to characterize the macrophysical, microphysical, radiative, and dynamical properties of stratiform mixed-phase clouds.

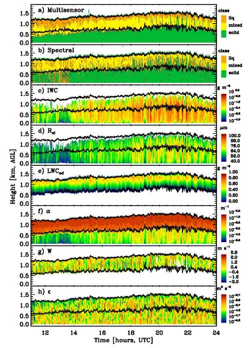

Figure 1. Retrieved cloud properties for 9 October 2004 at Barrow: (a) Multisensor cloud phase classification, (b) radar Doppler spectra cloud phase classification, (c) ice water content, (d) ice particle effective radius, (e) adiabatic liquid water content scaled to the microwave radiometer-derived liquid water path, (f) extinction, (g) vertical wind velocity (positive values are upward), and (h) turbulent dissipation rate. In each panel, the cloud liquid base and top are included.

Observations and/or retrievals are available for a number of mixed-phase cloud properties as demonstrated in Figures 1 and 2. Cloud boundaries are readily observed using radar and lidar, while these instruments team with various radiometers and radiosondes to provide an indication of cloud phase. A new retrieval of cloud phase also has been developed using cloud radar Doppler spectra. Vertically resolved and layer-averaged ice microphysical properties are derived from multiple combinations of radar, lidar, IR interferometer, and near-IR spectrometer. The liquid water path can be retrieved across a wide range of mixed-phase cloud conditions from observations at microwave, IR, and near-IR frequencies. Lastly, vertical wind velocity is available from cloud radar Doppler spectra measurements.

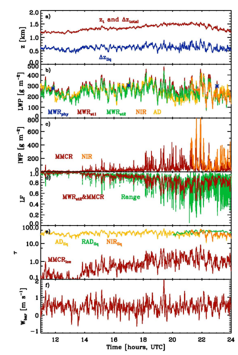

Figure 2. Retrieved cloud properties for 9 October 2004: (a) cloud top height and total (liquid+ice) thickness (red) and liquid layer thickness (blue); (b) liquid water path; (c) ice water path; (d) the liquid fraction, defined as the ratio of liquid water path to total condensed water path, given as the range from all measurements (green) and a possible best estimate (red); (e) optical depth of cloud ice and liquid; and (f) layer–mean vertical wind velocity (positive values are upward).

In spite of these successes, significant deficiencies remain in our ability to characterize some fundamental properties of mixed-phase clouds. Perhaps the most important of these is a general inability to vertically characterize the liquid water microphysical and radiative properties. Radar measurements are usually dominated by the cloud ice component, while lidar and spectral IR measurements are unable to penetrate the full liquid water layer in all but the thinnest clouds. Most radiometric measurements provide only a column perspective and are unable to vertically distribute cloud liquid properties. In addition to these liquid water difficulties, there are very limited means for characterizing the ice crystal habits and cloud-aerosol interactions from currently available ground-based sensors.

All-in-all, the ACRF sites contain several instruments that are quite useful for observing mixed-phase clouds. While our current abilities represent significant advances towards characterizing mixed-phase clouds, further validation studies, such as the Indirect and Semi-Direct Aerosol Campaign (ISDAC) from spring 2008, are needed to evaluate, improve, and expand our retrievals. Beyond validation activities, many of the remaining gaps will likely require the development of new instruments and measurement techniques.

Reference(s)

Shupe, MD, JS Daniel, G De Boer, EW Eloranta, P Kollias, E Luke, CN Long, DD Turner, and J Verlinde. 2008. "A focus on mixed-phase clouds: The status of ground-based observational methods." Bulletin of the American Meteorological Society, accepted for publication in October 2008 issue.

Working Group(s)

Cloud Properties